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Trace Element Analysis by Proton-Induced X-ray Excitation

F. C. Young[1]

Department of Physics and Astronomy, University of Maryland, College Park, Maryland 20742. Present address: Naval Research Laboratory, Washington, D.C. 20390

ABSTRACT

A new technique for detecting trace elements by exciting characteristic X-rays through proton bombardment is described. Typical results from analyses of algae, perch blood serum, perch liver, and sediment samples are presented.

Today I want to bring to your attention a new technique for trace element analysis that should be useful in evaluating many pollution problems of the Chesapeake Bay. The technique involves the excitation of atomic X-rays by bombardment with energetic protons. The X-ray production probabilities for such bombardments are sufficiently large that only small sample size is required. For example, one drop of blood is sufficient to detect trace elements in blood.

The technique is described schematically in Fig. 1. A beam of protons from the University of Maryland 3 MV Van de Graaff accelerator is incident upon a target sample. The incident protons pass through the thin target and lose a small fraction of their energy in the target by interaction with electrons in the target. Some protons remove electrons from the K-shell of atoms in the target with subsequent characteristic X-ray emission. The X-rays leave the target and pass through a 1-mil Be window on the target chamber and into a Si(Li) X-ray detector. It is the development of this high resolution detector that makes this technique so feasible and attractive. An X-ray from the target is completely absorbed in the active volume of the detector, producing an electronic signal of amplitude proportional to the incident X-ray energy. These signals are amplified and stored in a multichannel pulse-height analyzer. A measurement of the energy of the characteristic X-ray identifies the element in the target from which the X-ray originated. Knowledge of the number

[1]The author is an experimental nuclear physicist by training and has carried out numerous investigations into the structure of the light nuclei using nuclear reactions induced by ions from Van de Graaff accelerators. His recent interests have extended to using positive ions in studies of radiation effects, atomic physics, and trace element detection.

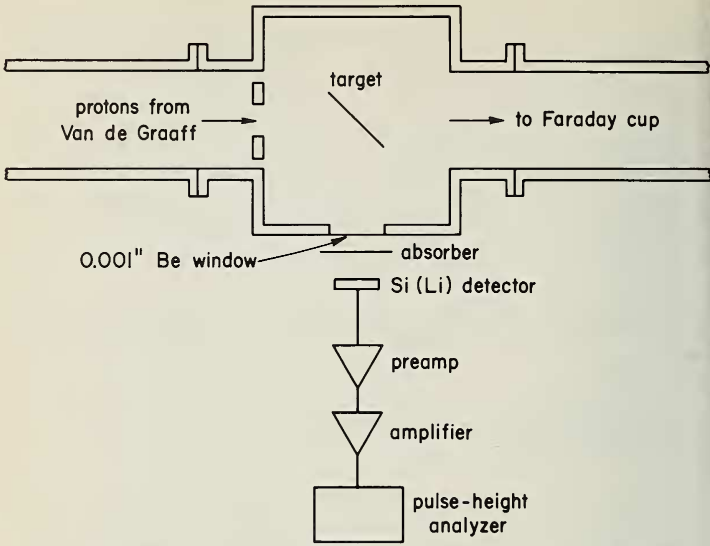

Fig. 1.–Experimental layout of the apparatus used for proton-induced X-ray excitation measurements.

of X-rays of a given energy indicates the quantity of the element in the target.

Several attractive features of this technique should be noted. Only a small quantity of a sample is required. In a given measurement all elements from silicon to uranium can be detected. A single measurement takes only 5-10 minutes, and samples can be remeasured with various absorbers between the target and detector to accentuate the detection of some elements relative to others.

This technique is currently being developed to detect the presence of trace elements in a variety of materials, including samples relevant to the Chesapeake Bay. The spectrum obtained from an algae sample is shown in Fig. 2. The X-ray energy is scaled along the horizontal axis, and peaks in the spectrum are labeled by the element corresponding to the characteristic X-ray energy. For elements lighter than the rare earths, K_α X-rays are strongly excited. Weaker K_β X-rays are observed for K, Fe, and Zn. For elements heavier than the rare earths, L-shell X-rays are strongly excited. The L_α and L_β X-rays for Pb are observed in this algae spectrum.

Pulse-height spectra measured for perch liver and perch blood samples are shown in Fig. 3. In addition to the many lighter elements identified in these spectra, there is positive evidence for the presence of Br in the perch blood serum and Se in the perch liver. The quantity of these elements present is of the order of ppm, and procedures are being developed to quantify such measurements.

For the measurements the samples were mounted on filter paper backings. This backing contributes very little to the trace elements observed but is responsible for a significant bremstrallung continuum which limits the detection of very small quantities. For comparison a pulse-height spectrum obtained from a sediment sample deposited on a thin carbon foil ($\sim$100 times thinner than the filter paper) is shown in Fig. 4. Nineteen

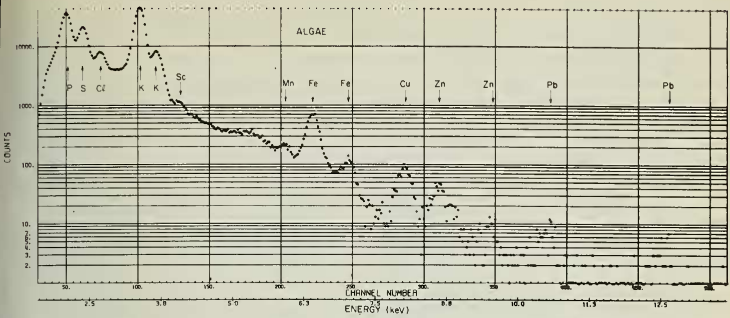

Fig. 2.–Pulse-height spectrum of X-rays from an algae on filter paper sample excited by 2.5 MeV protons.

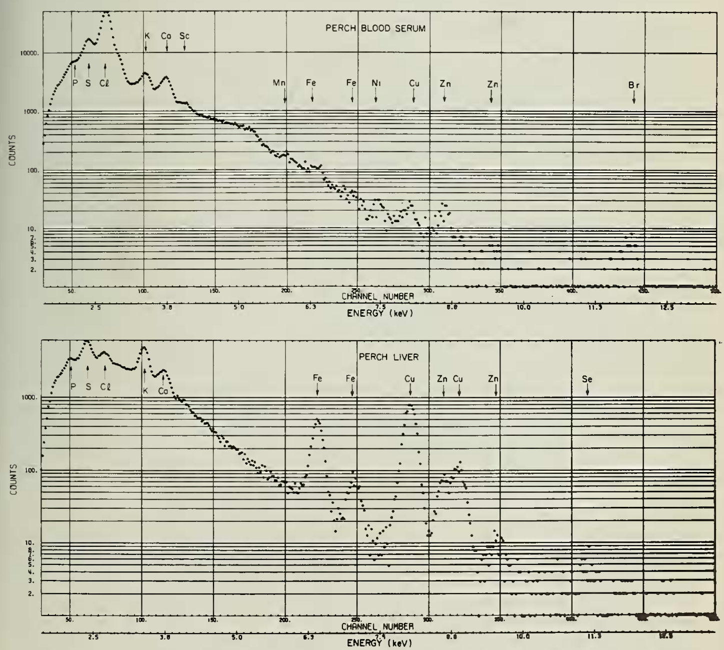

Fig. 3.–Pulse-height spectra of X-rays from perch liver (top) and perch blood serum (bottom) samples on filter paper excited by 2.5 MeV protons.

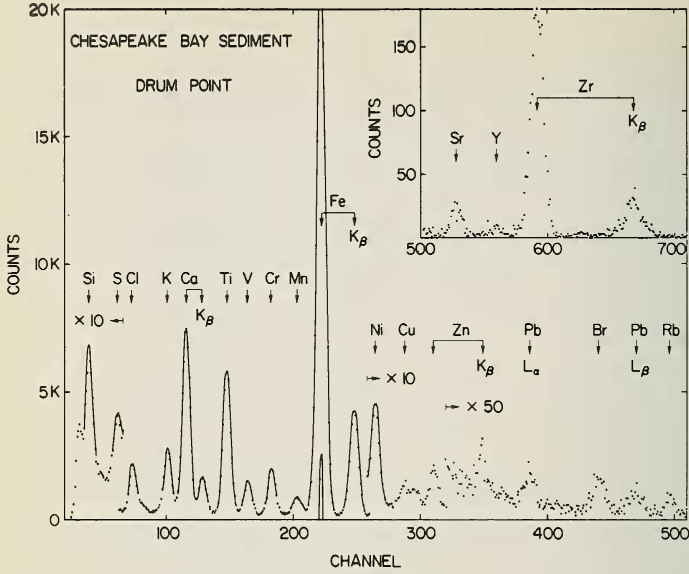

Fig. 4.—Pulse-height spectrum of a sediment sample taken from the Drum Point region of the Chesapeake Bay excited by 2.5 MeV protons.

different elements are positively identified in this spectrum, and the continuum in the lower portion of the spectrum is greatly reduced compared to the previous spectra.

Acknowledgments

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